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16. ABSTRACT

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PREDICTING FUTURE WATER DEMAND

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ABSTRACT: Decentralization within metropolitan areas has been a major aspect of population movement in the United States over the past two decades. This trend has great significance for all urban service activities. In particular, it affects water supply planning in urban areas. Both numbers of people and their spatial location affect forecasting of water supply demands which, in turn, affect fixed plant investments (source works, treatment works, transmission lines, distribution systems, and so forth) which are frequently built many years in advance of the resulting services. This paper describes, via a case study, the use of population and per capita demands as a basis for forecasting water requirements. Water use is studied according to residential and nonresidential demand. These data, combined with extrapolated demand coefficients, can be used as the basis for demand forecasting that not only provides estimates of quantity of demand but location of demand as well.

INTRODUCTION

Decentralization within metropolitan areas has been a major aspect of population movements in the United States over the past two decades (5). This trend has great significance for all urban service activities. In particular, it affects water supply planning. Provision of urban water services involves large capital investment expenditures, long lead times in planning and construction, and heavy fixed costs. Much construction must be undertaken well in advance of established demand because of the need to take advantage of economies of scale and the need for coordination with other urban services within a given area.

The service provided by the water industry is one of critical importance. The standard of life and health to which we are accustomed would be unattainable in the absence of properly functioning systems for the supply of water and the removal of waterborne waste. The water industry, therefore, is both relatively large and essential; issues that are important to the water industry are important to the nation as well. One issue of major importance to the water industry is the problem of forecasting future demands for water and wastewater services (2).

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This paper will explore a technique for water demand forecasts based on residential and employment figures. In addition to issues related to total water demand, the spatial location of these demands will also be explored. The analysis will be presented in terms of a case study conducted for the Washington Metropolitan Area (WMA).

Case Study Area

The Metropolitan Washington Area is defined as shown in Fig. 1. Included are the counties of Loudoun, Prince William, Fairfax, and Arlington. The independent cities of Alexandria and Manassas Park in Virginia; the counties of Montgomery, Prince Georges, and Charles (not shown in Fig. 1) in Maryland; and the District of Columbia are also included (3).

The problems of assuring an adequate potable water supply to the WMA has been a subject of intense debate for at least 15 years, and of concern for many more (1). The crucial issue is the growing reliance on the Potomac River as a source of drinking water for the WMA. Under most flow conditions, the volume of water in the Potomac River far exceeds present or projected needs. However, because the river flow is essentially unregulated and is subject to extreme fluctulations over short periods, concern exists that water supply shortages may result from the simultaneous occurrence of a maximum water demand and a low flow.

Fig. 2 shows the problems of depending on the Potomac River for water supply. The figure shows the 1966 flow of the Potomac, using the Point-of-Rocks river gage vs. 1973 total water withdrawals and the projected year 2030 monthly

FIG. 1.—Major Jurisdiction in Washington Metropolitan Area Considered in Study

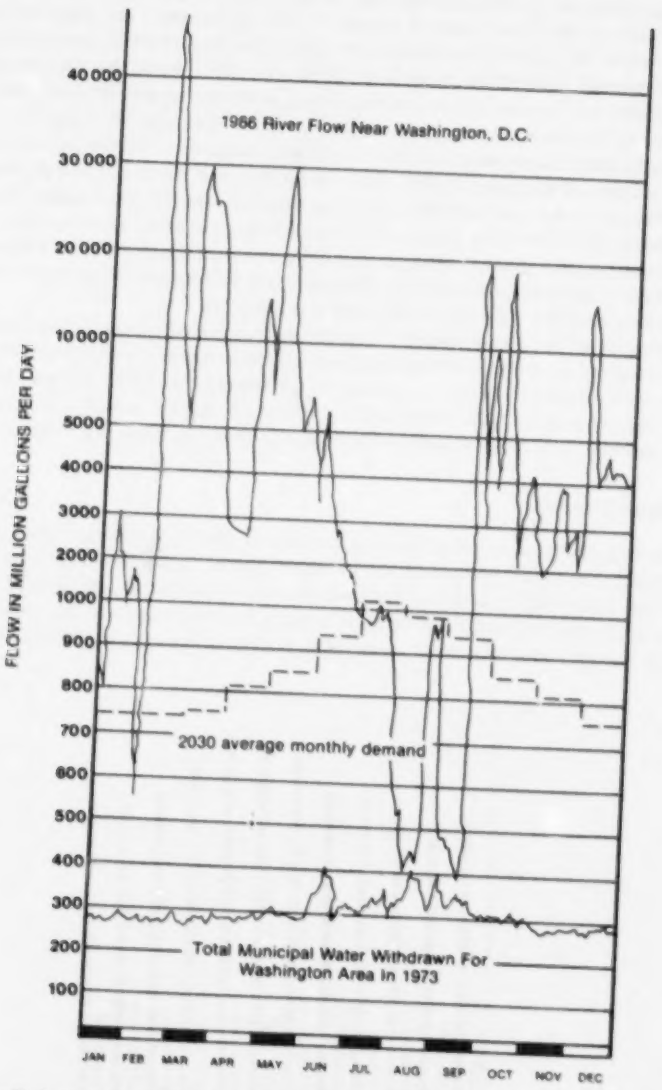

FIG. 2.—Hydrograph of 1966 Potomac Flow near Washington D.C. versus 1973 Municipal Withdrawal and Projected 2030 Average Monthly Demand

demand (6). The Point-of-Rocks gage is the closest reliable stream-flow measuring device on the Potomac upstream of the WMA water supply intakes. The 1966 flow is the lowest flow of record (7). As can be seen, the peak demand for water in 1973 nearly exceeds the low flow of the river in 1966. The projected 2030 monthly demand far exceeds the 1966 river flow. From this comparison, if demand for Potomac water increases future shortages apparently could occur.

Two of the three major water suppliers in the WMA—the Washington Suburban Sanitary Commission and the Washington Aqueduct Division of the U.S. Army Corps of Engineers (COE)—rely on the Potomac River as a major source of drinking water. A third major regional supplier—the Fairfax County Water Authority (FCWA)—now uses the Occoquan Reservoir as its major source, but has recently been granted a permit to build a Potomac River intake. Therefore, all three water purveyors view the Potomac River as a means of meeting current or future demands for water in their service areas (1).

Because of the issues related to current and projected demands, forecasting for water use is of extreme importance in the WMA. Rapid population dispersion and the problems of peak vs. average usage require that water planners know not only how much water is needed but where it is needed as well. Techniques for making these determinations will be analyzed in the following sections.

Current Demand

In this paper, two types of demand will be considered. One is raw water (RW) demand; i.e. water pumped to the treatment plants. The other is revenue producing water (RPW) which is the water for which revenue is actually obtained. The difference between RPW and RW is the water lost because of backwashing, leaks, meter errors, and other nonrevenue producing uses, such as fire fighting.

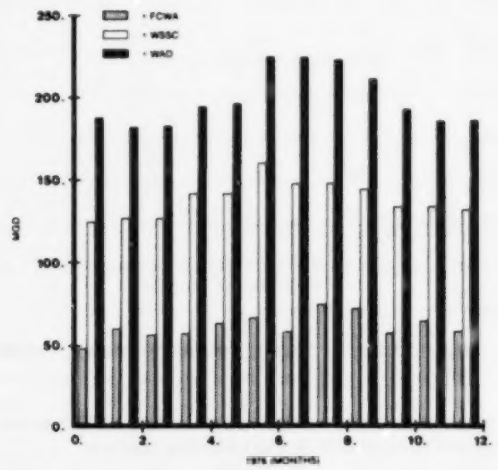

FIG. 3.—Average Raw Water Pumped by Major Purveyor

TABLE 1.—Demand Ratios for Washington Metropolitan Area

Month (1)	Ratio of Average Month to: Peak monthly average (2)	Peak seven days (3)	Peak one day (4)
July	1.19	1.27	1.41
August	1.16	1.33	1.48
September	1.10	1.20	1.28
October	1.00	1.03	1.08
November	0.95	0.99	1.01

TABLE 2.—Revenue Producing Water and Ratio of RPW to RW by Major Purveyor

Major purveyor (1)	Revenue-Producing Water: 1968, in millions of gallons per year (2)	1976, in millions of gallons per year (3)	Percentage of increase (4)	Ratio of Revenue-Producing Water to Raw Water: 1968 (5)	1976 (6)	Percentage of increase (7)
WAD	47,145	55,335	17	0.64	0.73	14
WSSC	31,000	42,000	35	0.64	0.83	30
FCWA	14,866	22,169	49	0.86	0.80	−7
Rockville	1,113	1,501	34	0.80	0.80	0
Leesburg	104	266	156	0.78	0.90	15
Total	94,228	121,271	29	0.74	0.78	5

TABLE 3.—Numbers and Types of Customers for Washington Suburban Sanitary Commission (1977)

Customer class (1)	Number of accounts (2)	Consumption (3)
Residential	11,970	8,000,000
Commercial	1,698	1,959,000
High-rise	21	9,200
Garden apartments	10	54,500
Federal	34	1,470,000
State	10	460,000
County	226	1,120,000
Industrial	0	—*
Institutional	1	1,700
Total	13,970	13,072,400

*Information not available

For the three major purveyors in the WMA—WSSC, WAD, and FCWA—the ratio of RPW to RW is 1.216; in other words, approximately 22% of the raw water in the WMA is used for nonrevenue producing purposes. RW reflects hydraulic capacity requirements for the acquisition and treatment systems, but RPW is the basis upon which a utility must plan its budget.

Raw Water Demand.—Total demand on the Potomac has remained essentially constant over the last 10 years, while demand on the Occoquan, Patuxent, and ground water has increased sharply. The capacity of these three sources has or will soon reach dependable yield limits and any future RW demand will, therefore, come from the Potomac.

The average monthly raw water pumped for 1976 by the three major water purveyors is shown in Fig. 3. Annual average monthly demand is less than the average monthly demand for June through September. Clearly, this shows peak demand is during the summer. Demand for water obviously varies significantly over time.

Four categories of demand will be used in this paper to represent this time-dependent characteristic. "Average month" means the sum of the average water use for an individual year divided by 12. "Peak month" is the highest single monthly demand within a given year. "Peak 7 days" means the highest seven-day running average for the year and normally occurs during the peak month. "Peak day demand" is the highest one-day demand in a given year and also generally occurs during the peak month. These categories apply to both RW and RPW.

Average monthly demand is probably the most stable and most easily calculated value. Therefore, the ratios of the various peak demand categories were calculated with respect to average monthly demand. Calculations were made for the ratios of average monthly demand to peak monthly demand, peak seven-day demand, and peak one-day demand. These values were calculated for the entire WMA and are reported in Table 1. As can be seen, the highest ratio of average monthly to peak monthly demand occurs in July; but peak seven-day and one-day ratios are higher for August. These ratios are important for estimating future demand and characteristics. Average monthly demand, for example, can be calculated based on population growth and estimated per capita water use in a given year. Once this projection has been made, ratios such as those presented in Table 1 can be used to estimate peaking characteristics as will be seen.

Demand for Revenue Producing Water

Table 2 shows the demand for RPW and ratio of RPW to RW for the WMA by major purveyors for 1968 and 1976. Table 2 shows that RPW has remained relatively constant as a percentage of RW over the nine-year period between 1968 and 1976. Fig. 4 shows a plot of demand for all five major purveyors.

Components of Demand.—As reviewed earlier, the basis for financial planning in a water utility is RPW. RPW, however, is supplied to various types of consumers. The rates charged these consumer classes are established according to utility accounting procedures. Each consumer class has its own growth and demand characteristics and understanding these various classifications is important. Table 3 shows various consumer classes for the WSSC. Column two shows

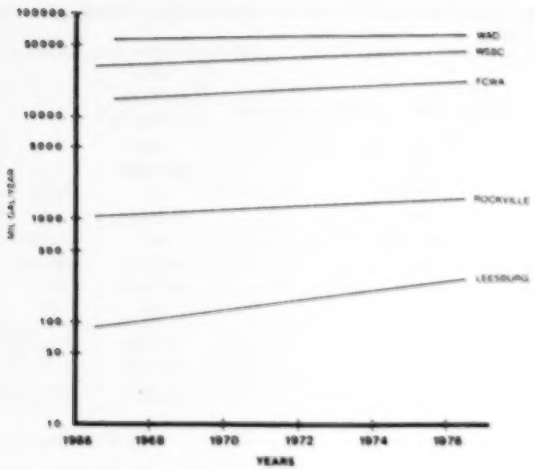

FIG. 4.—Revenue Producing Water by Major Purveyor

the meter and accounts for each class. For example, there are 21 high-rise buildings which are separately metered. Few utilities have such a detailed breakdown of the types of customers they serve. Because demand characteristics differ among customer classes, knowing the types of customers to which water is supplied is helpful. Unfortunately, none of the other utilities had as detailed a categorization of water use as did WSSC. In fact, the only two categories for demand common to all of the utilities were residential and nonresidential demand.

Therefore, for purposes of the analysis reported here, the demand categories were broken into residential use and nonresidential use. Residential use was assumed to be a function of the number of people residing in a water service area, and nonresidential use was assumed to be a function of employment. This assumption was made because most of the nonresidential demand was associated with commercial and manufacturing employment. In addition, spatial data is available in the WMA based on distribution of employment.

Table 4 shows the total RPW demand, total residential population, total employment, and per capita residential and nonresidential consumption for the District of Columbia (DC), Department of Environmental Service (DES), WSSC, and the combined Virginia utilities (FCWA, Arlington, and Falls Church). The figures show that consumption varies widely within the residential and nonresidential categories. One can theorize about some of the differences in demand shown in Table 4. For example, the low per capita residential consumption in D.C.-DES may be a result of the number of apartments and condominiums in the D.C. area thereby reducing household water use. In the WSSC and Virginia service areas, many of the residences are single-family homes in which lawn watering is a major factor in water demand.

Nonresidential consumption for D.C.-DES is very high, which may be a result of the large number of older office buildings. For WSSC and Virginia, nonres-

TABLE 4.—Residential and Employment Demand for Major Washington Metropolitan Area Utilities (1976)

Utility (1)	Yearly Residential Demand[a]		Yearly Nonresidential Demand		Total revenue-producing water demand, in millions of gallons per year (6)	Total residential population (7)	Total employment (8)
	In millions of gallons (2)	In millions of gallons per capita (3)	In millions of gallons (4)	In millions of gallons per capita (5)			
D.C.-DES	13,260	0.018	34,440[a]	0.052	47,700	741,000	660,100
WSSC	32,090	0.026	9,900	0.022	42,000	1,228,920	444,700
Virginia	32,904	0.035	7,680	0.019	40,600	943,800	410,400

[a]Includes apartments.

idential use is lower than in D.C. itself. Most employment in the suburbs is in small businesses or commercial establishments. Many of these facilities are new and may have better water usage controls. D.C.-DES also has a large transient population of tourists and daytime office workers who live in the Virginia suburbs. The office workers who work in but live outside of D.C. may contribute to high water usage in the nonresidential category for D.C.-DES and in the residential category for Virginia and WSSC. The water used by many Federal installations, such as the Pentagon, Andrews Air Force Base, Washington National Airport, and the Defense Mapping Agency, is also included in the nonresidential category.

Although these categorizations are gross, dividing water usage into residential and nonresidential demand was the only consistent basis for analyzing demand patterns among different types of customer classes. There is also a need to be consistent with the projection base which for nonresidential consumption is employment. In the following sections, residential and nonresidential demands are used to project water usage for the WMA.

Future Demand

The WMA covers 2,326 square miles and is growing most rapidly at its fringes (4). Growth patterns significantly affect both the quantity and location of demand for water in the WMA. For purposes of this paper, data from the U.S. Army Corps of Engineers (COE) and the Washington Metropolitan Council of Governments (MWCOG) were used as the basis for population and employment projections (4,6).

The two determinants used to calculate water demand for the WMA were population and employment. Population was used as the basis for residential water demand in the WMA and employment data provided the estimates of commercial and industrial water use.

Residential Population.—The COE's estimates were made by political sub-

TABLE 5.—Population Forecasting Equations[a]

Service area (1)	Equation (2)
WAD	$Y = 570.0 + 400.0\,X$
Arlington	$Y = 550{,}250.0 - 179.0\,X$
Fairfax City	$Y = 134{,}180.0 + 79.0\,X$
Alexandria	$Y = -1{,}960{,}960.0 + 1{,}060.0\,X$

[a]Y = population; X = year of projection (e.g., 2050).

division for 1970, and from 1980–2030 in five year increments. The MWCOG's were made at the traffic zone level for 1970, 1980, 1985, 1990, and 1995.

Regression equations (Table 5) were developed based on COE data to project the population to the year 2050 for those utilities whose service area corresponds to the political boundaries. Those utilities include the Washington Aqueduct, Arlington, Fairfax City, and Alexandria. The equations were based on COE estimates from the years 2000–2030. Several approaches to model development were attempted, including log-log and multivariate models. Simple linear regression models, however, were finally chosen for use in the analysis.

In Falls Church, Virginia, the service area corresponds to a specific set of traffic zones. The population for 1975 was estimated using the average population for 1970 and 1980 from the MWCOG data. A regression equation was developed from the 1970–1995 data to project population growth to the year 2050 at five year increments:

$$Y = -4{,}094{,}800 + 2{,}140\,X \quad \ldots\ldots (1)$$

in which Y = population; and X = year of projection (e.g., 2000).

The other small water utilities did not have service area boundaries that corresponded with either political or traffic zone boundaries. In those traffic zones split by a utility, street maps were used to identify the populated areas and the percentage of a traffic zone's population in each service area was calculated using MWCOG data. When the population served by each utility was determined for 1970, the same techniques used for the Falls Church service area were utilized to predict population through the year 2050 at five year increments. The regression equations are contained in Tables 6 and 7.

Although the COE made population projections for WSSC and FCWA, those service populations had to be adjusted downward to account for the independent utilities listed earlier by subtracting their populations. Regression equations were derived from the 1975–1995 data to project populations to the year 2050 as in the previous two examples. The equations for WSSC and the remainder of Fairfax County are, respectively:

$$Y = -53{,}374{,}374.0 + 27{,}624.0\,X \quad \ldots\ldots (2)$$

$$Y = -31{,}352{,}970.0 + 16{,}081.0\,X \quad \ldots\ldots (3)$$

Employment Forecasts.—Employment estimates in the service areas of water utilities in greater Washington, D.C., are based on the Metropolitan Washington Council of Government's 1974 Regional Employment Census and the MWCOG's

TABLE 6.—Regression Equations: Population Forecasting Equations

Service area (1)	Equations (2)
Fort Belvoir	$Y = -108{,}070 + 62.00\,X$
Reformatory	$Y = -84{,}248.0 + 44.4\,X$
Herndon	$Y = -1{,}983.0 + 1{,}010.4\,X$
Clifton	$Y = -44{,}208.0 + 22.6\,X$
Occoquan	$Y = -2{,}183{,}305.0 + 1{,}125.5\,X$
Dumfries	$Y = -558{,}545.0 + 287.3\,X$
Virginia American	$Y = -647{,}850.0 + 340.0\,X$
Manassas	$Y = -763{,}233.0 + 392.0\,X$
Rockville	$Y = -68{,}718.0 + 56.0\,X$
Leesburg	$Y = -356{,}570.0 + 184.0\,X$

Note: Y = population; X = year of prediction (e.g., 2030).

TABLE 7.—Regression Equations: Regression for Estimating Employment Levels[a]

Service area (1)	Equations (2)
WAD	$Y = 623{,}340.0 + 35{,}460.0\,X$
WSSC	$Y = 337{,}800.0 + 82{,}858.7\,X$
Rockville	$Y = 17{,}458.9 + 3{,}111.0\,X$
Arlington	$Y = 126{,}860.0 + 12{,}855.0\,X$
Falls Church	$Y = 50{,}250.4 + 9{,}832.4\,X$
Fairfax City	$Y = 16{,}530.0 + 2{,}180.0\,X$
Herndon	$Y = 1{,}090.0 + 1{,}031.7\,X$
Clifton	$Y = 28.0 + 14.0\,X$
Alexandria	$Y = 45{,}420.2 + 7{,}432.4\,X$
Fort Belvoir	$Y = 19{,}180.0 + 1{,}000.0\,X$
Dulles Airport	$Y = 2{,}394.9 + 498.8\,X$
Greater Manassas	$Y = 3{,}414.9 + 250.5\,X$
Virginia American	$Y = 510.4 + 1{,}262.4\,X$
Occoquan	$Y = 4{,}765.2 + 1{,}926.2\,X$
Dumfries	$Y = 995.1 + 1{,}108.1\,X$
Reformatory	$Y = 1{,}060.0 + 210.0\,X$
Remainder of Fairfax Co.	$Y = 60{,}722.5 + 29{,}380.5\,X$
Leesburg	$Y = 2{,}620.4 + 82.4\,X$

[a] Y = number of employees; X = year of projection (e.g. 2030).

employment forecasts for the period 1972–1995.

Traffic zones in the Metropolitan area were matched against the utilities' service areas. For those traffic zones contained in more than one service area, the percentage of the total employment in each utility area was estimated for 1972 using employment maps. These same percentages were used to allocate employment for the years of 1980, 1985, 1990, and 1995. Once the employment in the traffic zones was allocated to the service areas, total employment in each utility service area was calculated. The employment for each utility was estimated in five year increments for the years 2000–2050, based on regression equations

derived from the 1975–1995 estimates. (Regression equations for the individual utilities are contained in Tables 6 and 7).

The MWCOG's 1974 regional employment summary was used to estimate employment in different categories, such as government, manufacturing, and trade. Once all the employment categories were summed for each service area, the percentage of the total breakdown was used to estimate employment in each category for all the years concerned.

Demand Scenarios.—The population and employment estimates derived from each water utility were used to estimate water consumption under different demand scenarios. For each utility and each forecasted year, population and employment figures were multiplied by appropriate use rates. In this way, estimating the total demand for water in the metropolitan Washington area at different times in the future was possible.

Two sets of annual use rates were estimated; one for residential, and the second for other consumption (employment). Three different areas were utilized for demand calculations: Washington Suburban Sanitary Commission, the Washington Aqueduct Service Area, and the Virginia utilities. Table 8 contains residential and employment demands in millions of gallons per capita per year and millions of gallons per employee per year, respectively.

The actual and projected population and employment growth figures were com-

TABLE 8.—Demand Rate for Service Areas

Area (1)	Residential rate, in millions of gallons per capita per year (2)	Nonresidential rate, in millions of gallons per employee per year (3)
Washington Aqueduct	0.018	0.052
WSSC	0.026	0.022
FCWA	0.035	0.019

TABLE 9.—Per Capita Water Usage Scenario

Scenario (1)	Description of per capita change over 10-year period (2)
1	Growth in per capita and per employee water usage over entire WMA of 10%.
2	Growth in per capita and per employee water usage over entire WMA outside of D.C. of 10%, but a decrease of 5% per capita and per employee use in D.C.
3	Maximum growth in per capita and per employee water usage over entire WMA of 5%.
4	No growth in per capita and per employee water usage over entire WMA: current use assumed constant.
5	Decrease of 5% per capita and per employee use in D.C., and constant (no increase) use elsewhere in D.C. area.
6	Decrease of 5% per capita and per employee use over entire WMA.

FIG. 5.—Future Water Use (Percentage of Change over 10 Year Periods) Under Different Water Demands

TABLE 10.—Projected Annual Requirement for Revenue Producing Water, in Millions of Gallons per Year (Based on Scenario 4)

Area (1)	1976 (2)	2050 (3)	Percentage of increase (4)
Washington	47,199	76,807	63
(millions of gallons per day)	(129)	(210)	(63)
Virginia	40,603	111,571	175
(millions of gallons per day)	(111)	(306)	(176)
Maryland	42,874	111,997	161
(millions of gallons per day)	(117)	(307)	(162)
Total RPW	130,676	300,075	130
(millions of gallons per day)	(357)	(823)	(130)

TABLE 11.—Washington Metropolitan Area Demand (in Millions of Gallons per Day) by Category

	1976		2050		Percent of Increase	
Item (1)	Revenue-producing water (2)	Raw water (3)	Revenue-producing water (4)	Raw water (5)	Revenue-producing water (6)	Raw water (7)
Average month	358.0	435.3	811.7	987.0	127	127
Peak month	413.8	503.2	970.5	1,180.0	134	135
Peak 7 days	475.4	578.7	1,079.0	1,312.0	126	127
Peak 1 day	529.7	644.1	1,201.0	1,460.3	127	127

bined with assumed residential per capita and per employee water demand to estimate total water demand for the WMA. Several scenarios were hypothesized and are summarized in Table 9. These scenarios ranged from a growth in per capita and per employee water use of 10% per 10-year period to a decrease of 5% per capita and per employee per 10-year period. Based on data developed earlier, Fig. 5 shows the resultant change in Potomac demand for the six different scenarios. These curves are based on the assumption that the Occoquan, Patuxent, and others supply a steady yield of 121 mgd. Table 10 shows projected water requirements for scenario 4 (constant water use). Line 1 of Table 11 shows the average monthly use based on the annual requirements listed in Table 10. Table 11 also shows various peaking requirements based on the average monthly use and the ratios in Table 1.

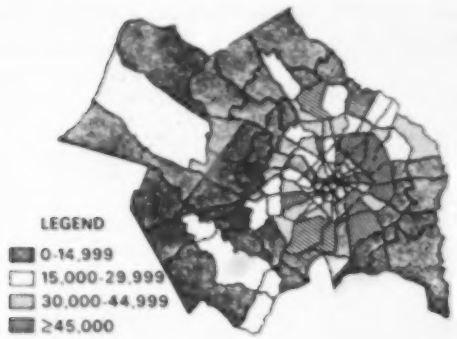

FIG. 6.—Population in Metropolitan Washington PAD (1970)

FIG. 7.—Population in Metropolitan Washington PAD (1995)

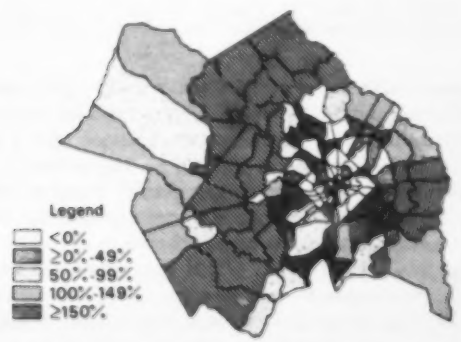

FIG. 8.—Percent Change in Population in Metropolitan Washington by PAD

The peak monthly demand for raw water in the year 2050 is expected to reach 1,180 mgd, which exceeds six of the minimum monthly flows attained at the Point-of-Rocks gage on the Potomac for the period of record. This disparity between projected demand and historical flow illustrates the problem that may ultimately face Potomac River water users.

Spatial Representation.—The data in Fig. 5 shows the various demands to be faced by Potomac users in the future. Another factor as important as total demand is the spatial location of the demand. To illustrate how these data can be used to determine the location of demand the following example will be developed. It incorporates segmenting the WMA into Planning Analysis Districts (PAD). Fig. 6 shows population by PAD in the WMA for 1970, and Fig. 7 shows the estimated population in 1995. Fig. 8 shows percent increase in population from 1970–1995. Because per capita water use is assumed constant, water demand will be proportional to population. These figures show the dramatic changes that may take place in the near future. PAD population and employment data were not available after 1995, but projections by political jurisdiction were available from the COE through 2030. The regression equations were used to extend COE's projections to 2050.

Analysis of Demands

As can be seen from the previous analysis, an estimate of total demand and location of demand based on population and employment changes over time is possible. These calculations can be used for design of facilities, location of transmission and distribution lines, and location of potential constraints on the availability of supply. As can be seen from Figs. 6–8, population (and employment) increases are most dramatic in the WMA suburbs. Population will actually drop in the District of Columbia itself although employment is somewhat more stable. In the following example the calculated demand projections are used to illustrate the problems associated with using the unregulated Potomac as the only source of additional raw water for the WMA. Fig. 9 is a plot of four different raw water demands and three different historic unregulated low flow conditions versus time (7). The solid lines represent the demand; i.e. raw average monthly demand. The dotted lines represent three historic low flows in the Potomac: seven-day, 1930; one-day, 1930; and one-day, 1966. The average monthly demand exceeds all three supply conditions after the year 2000. The other demand conditions exceed all three flow conditions at an even earlier date. The graph can be used to show the problem of water supply in the WMA. For example, in the year 2050 the projected RW peak one-day demand exceeds the 1966 one-day flow by nearly 1,100 mgd.

Comparing various flow conditions against demand projections provides insight into the capability of the Potomac to meet future demands. Fig. 9 shows, superficially at least, that even under the most optimistic conditions deficits will probably occur between 1990 and 2000. The basic issue in this analysis is the trade-off required to meet the various deficits, given any set of flow conditions.

For example, if additional source water could be provided to meet the deficit resulting from the occurrence of a one-day 1966 flow condition and the one-day peak demand in 2050, the risk of ever experiencing that flow deficit will be

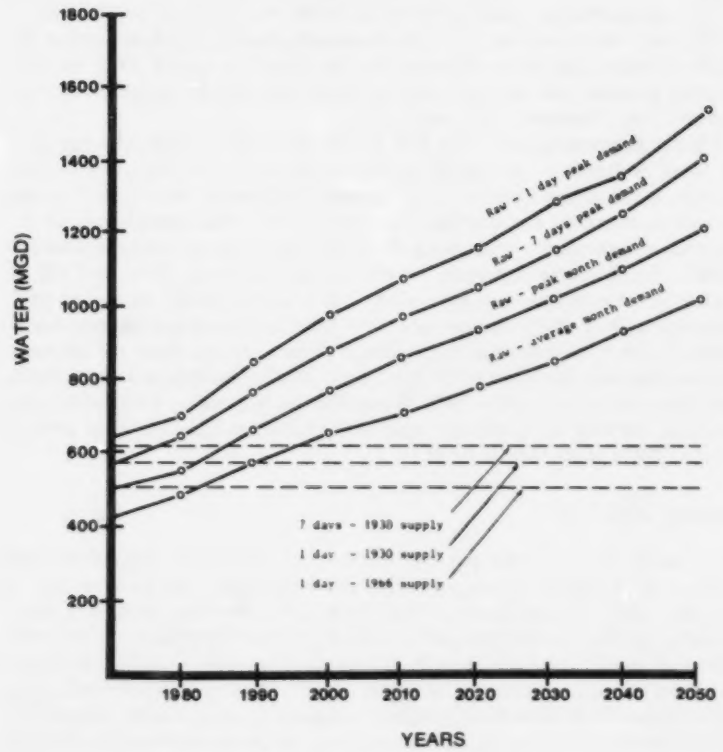

FIG. 9.—Supply and Demand Relationships

extremely low, but the associated cost may be high. If sufficient flow is provided to meet the simultaneous occurrence of the seven-day 1930 low flow and the average peak month demand for 2050, the requirement for additional source water is significantly less and therefore less costly, but the risk of a deficit may be great. One must, therefore, balance the risk of failing to meet demand on the one hand against the cost of augmenting supply on the other.

These population and employment projections provide the basis for making the critical decisions that must be made by every utility in order to provide adequate supply in the future.

Application of Technique to Other Areas

The techniques described in this paper can be extrapolated, with some effort, to other geographic areas. Most utilities record demands in more than one category, although few utilities have the number of demand categories established by WSSC. Few utility service areas have population employment, or both, by

PAD's or traffic zones as available in the WMA. Almost all utilities, however, have census tract data available which include residential population and various classifications of employment. In using the demand data together with the employment data one should be careful to be consistent. For example, if water demand is available by specific type of commercial establishment but the basis for projection is a much broader category such as total employment, then one is constrained to use the less precise information. Most areas have some form of population projection available based on a spatially defined unit such as a census tract. Simple linear regression equations as described in this paper are relatively easy to derive. These elements can be combined to give both the total water demands for an area and the spatial demand as well.

Summary and Conclusions

Decentralization within metropolitan areas has been a major aspect of population movement in the United States over the past two decades. This trend has great significance for all urban service activities. One issue regarding population changes that is demonstrably important to the water industry, and therefore to the nation, is the problem of forecasting future demands for water and wastewater services. A methodology for forecasting water demands in terms of spatial, location, and quantity has been reviewed. The technique is based on the estimation of water use by demand sector and by location of demand according to population and employment growth patterns.

This technique, as proposed, can show total demand as well as location of demand, peak requirements, average monthly demand quantities, and location of demand points.

Appendix.—References

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